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A Pathological Case in the Use of Subroutine HANS

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This is an unreviewed manuscript, primarily intended for informal exchange of information among NMC staff members.

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1. Introduction

The initialization of the analyzed wind field for use in the LFM model involves the removal of the divergence through the use of subroutine HANS. In anticipation of a potential use of this subroutine in the postprocessing section of the LFM, I undertook some tests of the subroutine using analytic input. For the most part these tests showed the subroutine to perform as expected; however, in two cases peculiar results were obtained.

2. Case 1

In one case, I found that the convergence criterion was not satisfied within the allowable number of scans (~200), but upon further investigation I found that the winds were adequately specified (<.1 m sec^{-1}error) by the 'nonconvergent' streamfunction. I don't discuss this case further in this note, since to my knowledge HANS has never failed to converge in operational practice.

3. Case 2

The pathology that I feel should be reported arose when I provided HANS with a purely irrotational wind field of the simple form.

$$u = +\,100 \quad - \quad 200\,\frac{x}{L_x}$$

$$v = +\,100 \quad - \quad 200\,\frac{y}{L_y}$$

in which u and v are in m sec^{-1} and L_x and L_y are the x,y dimensions of the grid (53 x 45) used in the calculation.

Instead of returning a zero wind field (as I expected) the subroutine returned a large-scale nondivergent wind field with components as large as 90 m sec^{-1}. The solution obtained for u and v is shown in figures 1 and 2.

4. The problem

Since the relative vorticity of the input wind is precisely zero, the erroneous solution must be excited by the boundary conditions used in the subroutine. These boundary conditions are fairly complex, (for details, cf. Gerrity, The LFM Model - 1976, in review process).

Involved is a construction* of the wind field outside the boundary. These constructed winds are used to calculate a relative vorticity at the center of the additional set of boxed formed by the points on which the outside winds are constructed and the boundary wind points. Finally, it is assumed that the normal derivative of the stream function vanishes between the midpoint of the boxes formed by the boundary and first interior rows of wind points, and the middle of the implied boxed lying just beyond the grid row containing the constructed wind.

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*The construction is via the rule

$$\vec{v}\cdot\vec{n}(\text{outside}) = \vec{v}\cdot\vec{n}(\text{inside})$$

$$\vec{v}\cdot\vec{t}(\text{outside}) = -\ \vec{v}\cdot\vec{t}(\text{inside})$$

$\vec{v}$ is the wind vector, $\vec{t}$ in tangent to boundary, $\vec{n}$ is normal to boundary

Note that for this case the construction of the tangential wind produces a vortex line along the line connecting the midpoints of the boxes just outside the boundary (see the diagram below)

	$\psi_1 \cdot$
reflected wind points	$\leftarrow +$ $\quad\quad\quad$ $\leftarrow +$ $\quad\quad\quad$ $\leftarrow +$
	$\Delta \quad \zeta \neq 0 \quad\quad \Delta$
outermost boundary wind grid points	$+ \rightarrow$ $\quad\quad\quad$ $+ \rightarrow$ $\quad\quad\quad$ $+ \rightarrow$
	$\psi_2 \cdot \zeta = 0 \quad\quad \cdot \zeta = 0$
first interior grid points	$+ \rightarrow$ $\quad\quad\quad$ $+ \rightarrow$ $\quad\quad\quad$ $+ \rightarrow$

Note that $\psi_2 = \psi_1$ is the normal derivative boundary condition.

The strength of the vortex line varies along the curve connecting the Δ points and the line integral all around the boundary is precisely zero in this case. This is of course necessary since $\zeta = 0$ in the interior.

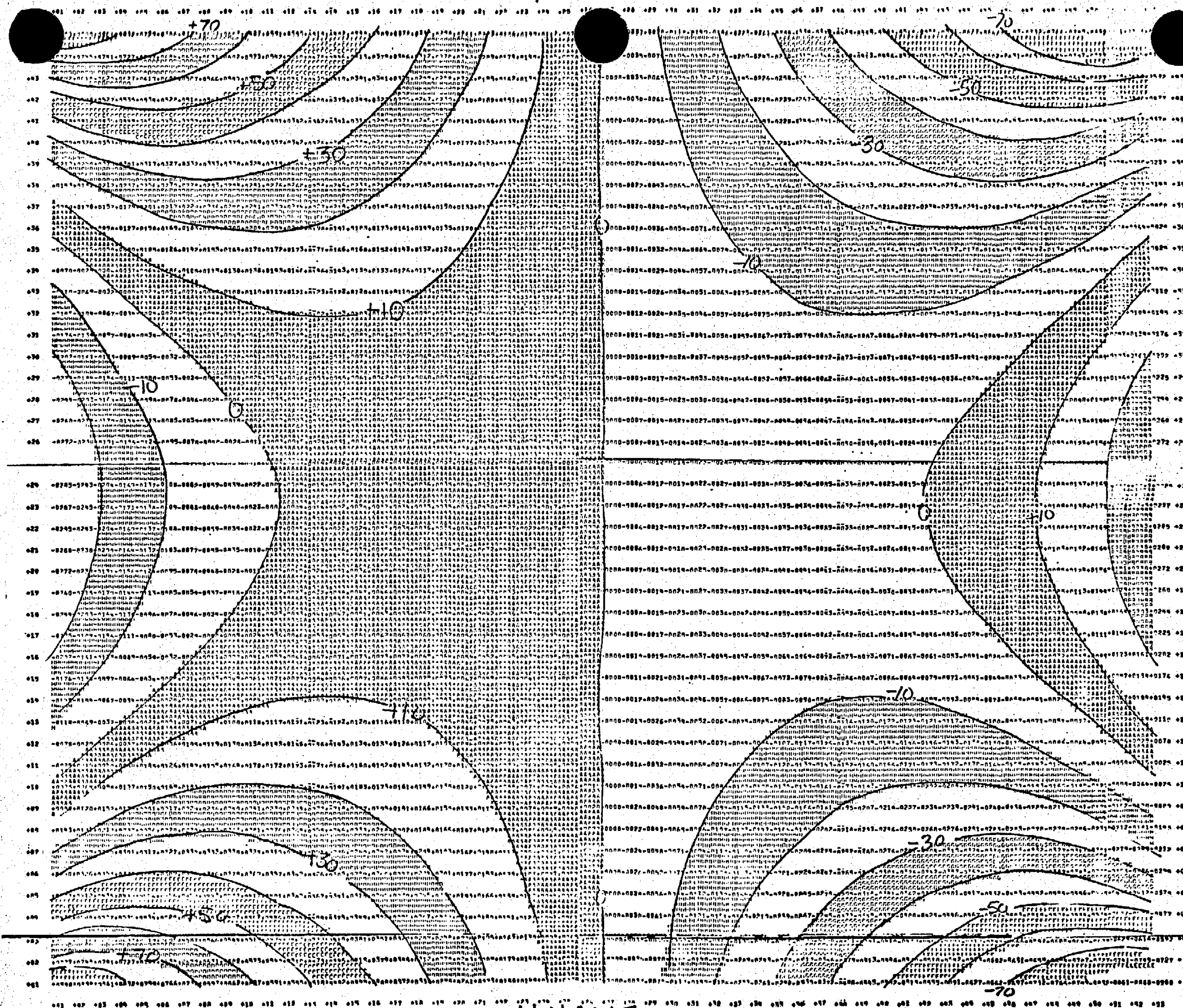
5. Status

At this point in the investigation, it is difficult to know how much significance to attach to the noted pathology. I have found much smaller errors to occur when HANS was provided a wind field constructed from the superposition of a modest sized irrotational wind and a reasonable nondivergent wind. So generally the method is reasonably accurate.

I plan to revise the boundary condition used in HANS and to examine the accuracy that is achieved. Before ending, it should be noted that removing the average inflow from the normal component of the boundary wind had a minuscule effect on the solution returned.

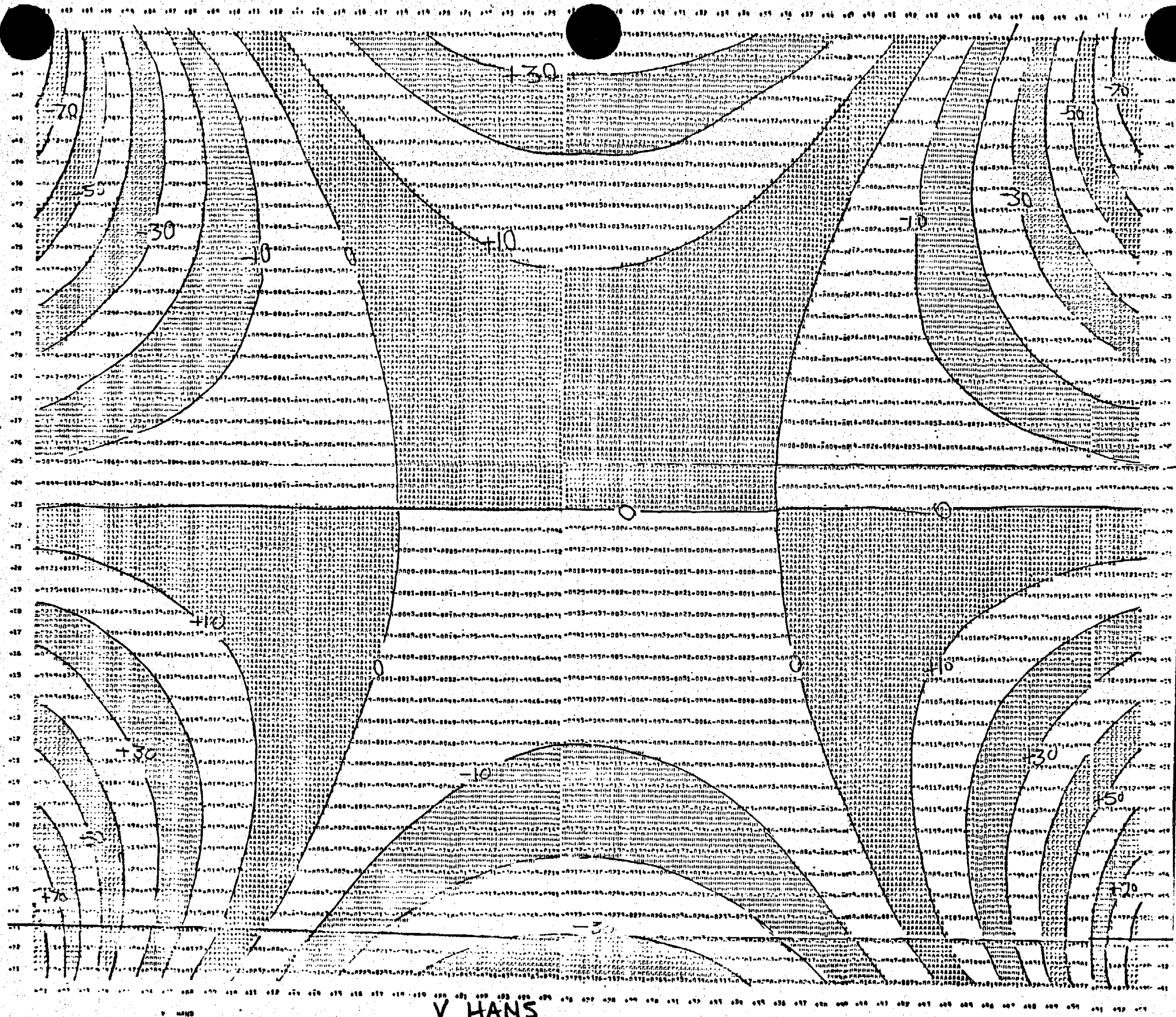
Acknowledgment

Bill Collins helped to identify the character of the problem.



U HANS

FIG I



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V HANS

FIG II